Talisker (Seaglider 156) Mission 001:

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Talisker (Seaglider 156)

Mission 001

Rockall Trough

12 October 2009 to 09 March 2010

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A winter survey of the Ellett Line

Internal Report No 272

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Summary

Talisker (SAMS Seaglider 156) was deployed west of Tiree on 12 October 2009, to undertake SAMS exploratory mission to monitor the Ellett Line in the North Atlantic using a glider rather than a ship. She was equipped with a Seabird CTD and Oxygen sensor as well as a Wetlabs fluorometer with red and blue backscatter sensors. Before recovery on 9 March 2010 she had made 789 dives, completed four crossings of the Rockall Trough and covered over 3000 km. Although the end of the mission was forced by a failure of the roll motor, by then all objectives had been completed and the glider was about to return home. The mission has thus been judged a success, and marks the start of remote monitoring of the North Atlantic by SAMS.

A complete summary of the mission data can be found at http://dalriada.sams.ac.uk/glider/

Contents

1. Introduction

The full record of all actions taken and commands given during the mission can be found in the Talisker log book. This narrative provides a succinct summary of the main activities and milestones that were achieved during Mission 1.

The Seaglider had been received from Seaglider in mid September 2008, but had subsequently been dogged by communication problems, which included: a faulty modem; flaky Iridium RUDICS transmission via the internet; and a faulty digitiser card in SAMS phone system. However, following trials in the Lynn of Movern in February and again in September 2009 by early October 2009 it was decided that Talisker was ready to undertake her first mission into the Rockall Trough.

Having kept a close watch on the weather for a week or so, Talisker was finally launched on 12 Oct 2009, although the precise position was a little to the north-east on the intended site because of boat drift during the set up phase.

She was finally by recovered NLB Pole Star on 9 March 2010, following a failure of the roll motor which left her stranded at the surface about 75 miles W of Tiree in the Rockall Trough.

In all she conducted 789 dives, collecting effectively 1578 CTD casts of data and 63% of her total power resource, which can be interpreted as a very successful mission.

2. Preparation

In planning this first mission there were a number of issues that it needed to test or resolve before we would know whether it was possible in the long run to deploy gliders operationally into the North Atlantic from Dunstaffnage. Specifically, the main ones were:

i) What would be the overall cost, in terms of finance and manpower, for the deployment and recovery phases? Could a glider be deployed directly from Dunstaffnage?

ii) Could a Seaglider safely track across the relatively shallow tidal waters of the Scottish Shelf? How much power would be used and how significant would tidal advection be?

iii) How much time and effort would be required to pilot the glider during its mission?

iv) Was there a real risk of run over by a trawler?

v) What would we do if it broke down?

Item iii) was of particular concern because at the time of deployment we did not have an operational website that would allow an easy way to monitor the progress of the glider.

In the period leading up to the deployment a number of boat operators operating from different locations around the west coast (including Northern Lighthouse Board) had been evaluated for their potential capability to deploy the glider in sufficiently deep and open water. Eventually, Coastal Connection - who operate two Redbay 11 m cabined RIBs out of Loch Feochan just south of Oban - were selected to deploy Talisker at 56° 30' N, 7° 30' W, about 15 nm west of Tiree. This location satisfied the requirement that it was within the boats safe area of operation, and sufficiently close to Dunstaffnage that a return trip could be made in a day (the ribs can do over 25 knots). It was also far enough out, and in sufficiently deep and open water, for Talisker to be able to reach the shelf edge without risk or using excessive battery energy and it was away from any shipping lanes. In addition RHIBs are low sided and have a soft hull which makes it easy to deploy and recover the glider over the side. The cabin is important as it allows one to operate a laptop under cover.

3. Mission Diary

The main events during the mission are given below. For more complete information consult the log book.

Date	**Dive no.**	**Location**	**Comment**
12 Oct	1	56.56 N, 7.48 W	First dive completed at 13:44 h. 24v 1.12 Ah
14 Oct	77	56.47 N, 7.84 W	Porpoising started
17 Oct	200	56.49 N, 9.02 W	At shelf edge 24v: 18.67 Ah
18 Oct	235	56.60 N, 9.39 W	Porpoising ended
19 Oct	241	56.63 N, 9.68 W	First deep dive in RT
26 Oct	283	57.26 N, 11.14 W	Anton Dohrn Seamount
30 Oct	301	57.35 N, 12.72 W	Bad GPS fix (58.22 N, 12.43 W) - false drift current
31 Oct	304	57.35 N, 12.82 W	At ROCK (Rockall Bank). 24v: 33.88 Ah
12 Nov	353	56.66 N, 9.02 W	At SHELFE (shelf edge). Round trip 1 completed. 40.63 Ah
19 Nov	380	57.13 N, 10.25 W	Arrested by strong eastward current S of Anton Dohrn Seamount
26 Nov	408	57.42 N, 10.82 W	On the Anton Dohrn Seamount
28 Nov	415	57.33 N, 10.74 W	Westward travel resumed just S of Anton Dohrn
7 Dec	449	57.26 N, 10.51 W	Switched off cap file upload to reduce power consumption and transmission costs
9 Dec	458	57.30 N, 10.69 W	Arrested by impenetrable eastward current S of Anton Dohrn. Allowed to continue without interference.
10 - 14 Dec	459 - 480	just S of Anton Dohrn	Experiment to see what happens with passive piloting in a strong opposing current. Result - no westward progress!

Date	Dive no.	Location	Comment
14 Dec	476		Science file altered (see below)
15 Dec	481	57.32 N, 10.67 W	Decide to go south to the HEBRIDE (Hebrides Terrace Seamount) to avoid eastward current
16 Dec	486		Communication lost due to basestation being switched off. Unable to command Talisker to go west
17 - 19 Dec	487 - 499	eastern Rockall Trough	Problems restoring communication. Strong current carries Talisker too far south.
20 Dec	500	56.64 N, 9.96 W	Finally picked up new target of ROCK (Rockall)
21 Dec	503	56.54 N, 10.25 W	Hebrides Terrace Seamount, now going west
29 Dec	532	57.39 N, 12.80 W	At ROCK (Rockall Bank). 24v: 63.26 Ah
13 Jan	592	56.68 N, 9.02 W	At SHELFE (shelf edge). Round trip 2 completed. 69.98 Ah
14 Jan	593	56.69 N, 9.04 W	Stuck on bottom at 545 m - emergency surfacing
25 Jan	636	57.28 N, 12.90 W	At ROCK (Rockall Bank). 24v: 75.15 Ah
28 Jan	647	56.84 N, 12.09 W	Broke off return trip to track through eddy
31 Jan	659	57.63 N, 12.13 W	Northernmost point of eddy investigation
04 Feb	673	57.24 N, 12.18 W	End of eddy investigation
14 Feb	708	56.69 N, 9.08 W	At SHELFE (shelf edge). Round trip 3 completed. 83.32 Ah
22-23 Feb	740 - 745	approaching Rockall	NAL Research disconnected Talisker for supposed non-payment of bills. No transmission
23 Feb	742	57.33 N, 12.78 W	At ROCK (Rockall Bank). 24v: 87.46 Ah
5 Mar	780	56.66 N, 9.14 W	At SHELFE (shelf edge). Round trip 4 completed. 92.13 Ah
8 Mar	789	56.58 N, 9.78 W	Final dive at 05:22 h. Roll motor failure.
9 Mar		56.72 N, 9.51 W	Recovered by NLB Pole Star

4. Vital statistics

4.1 Endurance

Talisker was at sea for a total of 148 days, or nearly 5 months. The approximate distance (as the crow flies) across the Rockall Trough from SHELFE to Rock is 250 km. Talisker did four round trips in 4.5 months and travelled 3000 km through water (but an effective 2000 km over land given the meandering route) in the process.

Dive	Date	No of days	24 v Ah	10 v Ah	24 v used	10 v used	24 v rate d^{-1}	10 v rate d^{-1}
001	12 Oct 2009 13:24	-	1.1 (0.7%)	0.8 (0.7%)	-	-		
200	17 Oct 2009 15:43	5.1	18.8 (12.8%)	4.8 (4.3%)	17.7	4.0	3.47	0.78
789	8 Mar 2010 05:22	141.6	93.2 (63.4%)	63.3 (56.5%)	74.4	58.5	0.66	0.52

Note: Quoted maximum power is 147 Ah (24 v battery) and 112 Ah (10 v battery).

The 24v battery used a total of 73.46 Ah (50%) to do four Rockall Trough round. Since SHELFE to Iceland is ~1000 km, a round trip along the extended Ellett Line looks very feasible.

Maximum duration on the shelf is ~ 143 days (10 v) and ~ 42.4 days (24 v). Maximum duration in the ocean is ~215 days (10 v) and ~ 223 days (24 v).

4.2 Costs

The costs for mission 1 are itemised below. Iridium costs are based on pstn - pstn transmission. A RUDICS connection was bought but not used due to technical problems.

Activity	Contractor	Date	Cost (£)	Comment
Deployment	Coastal Connection	12 Oct	625.77	
Recovery	Northern Lighthouse Board	9 Mar	3030.97	Fuel costs
Iridium	NAL research	13 Oct - 12 Nov	1201.91	Dives 15:357 @ £3.53 per dive
Iridium	NAL research	13 Nov - 12 Dec	735.98	Dives 358:471 @ £6.46 per dive (7 Dec: stopped cap file)
Iridium	NAL research	13 Dec - 12 Jan	514.12	Dives 472:585 @ £4.50 per dive
Iridium	NAL research	13 Jan - 12 Feb	563.78	Dives 586:703 @ £4.73 per dive
Iridium	NAL research	13 Feb - 12 Mar	508.51	Dives 704:789 @ £5.91 per dive
Transport to US			671.00	
Post mission servicing / calibration *	iRobot and Seaglider Fabrication	Autumn 2010	7083	
Total cost			14935.04	

* Includes VAT but not transportation. Does not include cost of the new Optode sensor, replacement hull (the original was pitted) which are seen as one-offs.

The total cost for Iridium transmission was £3524 (or about £700 per month).

5. Log file

An example of a successful dive (788) near the end of the mission is given in the appendix.

6. Targets file

The targets file at the end of the mission read.

Name	lat =	lon=	radius=	goto=	depth=
SHELFM	5627.0	-00750.0	4000	TIREE	
AD_CENTRE	5727.0	-1103.0	15000	AD_SOUTH	1000
AD_SW	5716.5	-1124.5	2000	ROCK	
AD_SOUTH	5712.5	-1103.7	2000	AD_SW	
AD_S_EAST	5712.5	-1103.7	2000	SHELFE	
ROCK	5722.8	-01252.0	5000	SHELFE	800
HEBRID	5627.5	-01023.2	5000	SHELFE	
SHELFE	5640.0	-00905.0	5000	ROCK	800
TIREE	5630.0	-00730.0	1000	TIREE	
EDDY_S	5647.8	-1209.0	2000	SHELFE	
EDDY_N	5736.8	-1209.0	2000	EDDY_S	

By the end of the mission the navigation plan had been reduced to simply transiting between SHELFE and ROCK.

7. Science file

After Dive 2:

```
   Depth       Time       G&C Sensors
    30.0m      10.0s      60.0s 111 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 1)
   200.0m      30.0s     120.0s 111 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 1)
  1000.0m      60.0s     120.0s 111 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 1)
```

After dive 476 the frequency of the Wetlabs sensors was reduced by a factor of 6:

```
   Depth       Time       G&C Sensors
   100.0m       5.0s      60.0s 116 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 6)
   500.0m      10.0s     120.0s 116 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 6)
  1000.0m      60.0s     120.0s 116 (SBE_CT: 1 SBE_O2: 1 WL_BB2F: 6)
```

8. Pictures

8.1 Deployment

Figure 1. Talisker in the Firth of Lorn on the way out to deployment, 12 Oct 2009

Figure 2. Colin Griffiths deploying Talisker

8.2 Recovery

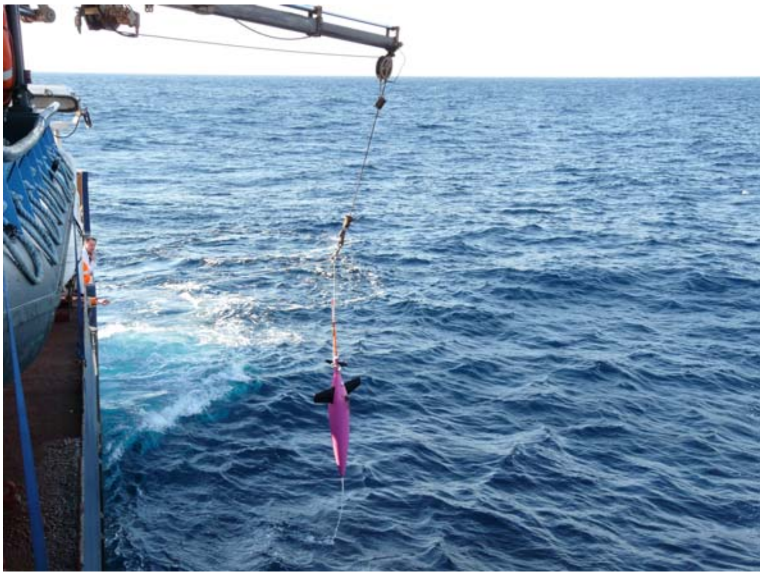


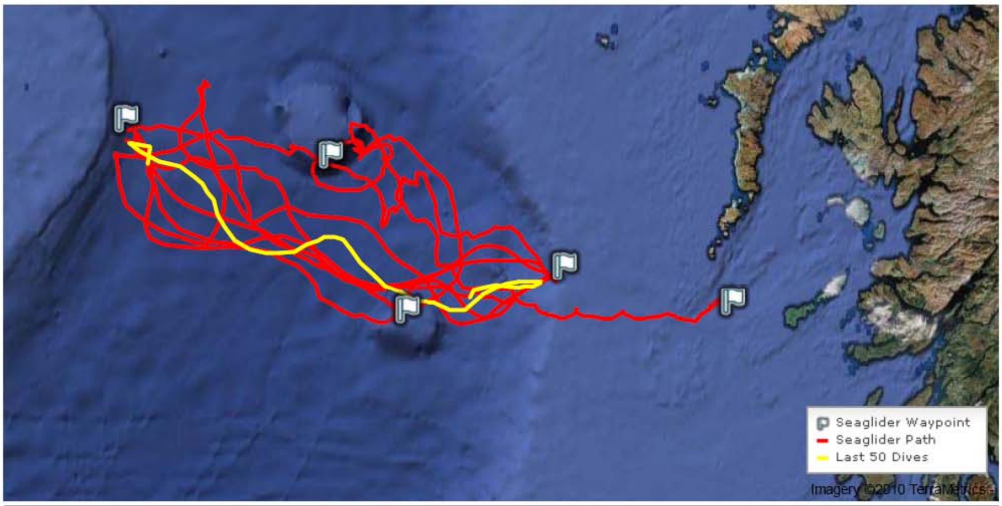
Figure 3. Recovery by NLB Pole Star, 9 March 2010

8.3 Webpage at end of mission

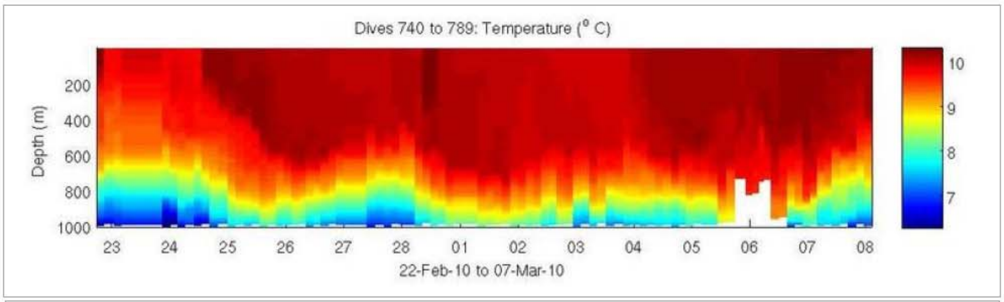
The Scottish Association for Marine Science

Talisker Seaglider

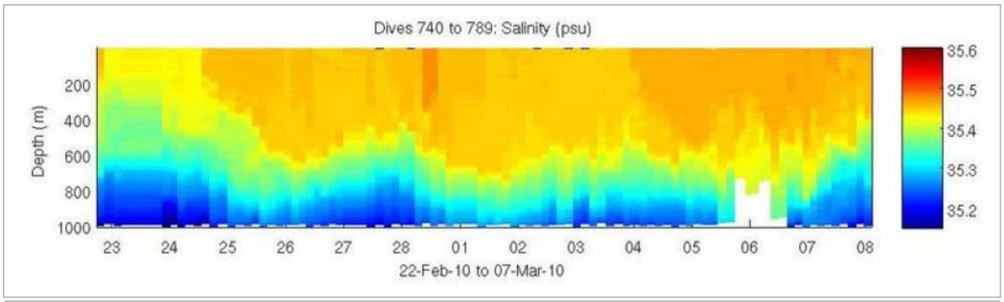
SAMS Seaglider (Talisker) :: Mission 1: To monitor the Rockall Trough



Mission 1 is now complete. Our Seaglider is currently on shore leave for service and calibration.
Latest dive, number 789 at 56.58 N, 9.78 W was received on 2010-03-08 05:22 GMT.
Zoom into the map to access plots and data for each dive or click on the plots below to access plots and data for the latest dive.



Temperature section from the last 50 dives.
The temperature of the Rockall Trough has risen by 1 deg C in the last 30 years -
using gliders we can monitor future changes and quantify the natural variability in the upper 1000 m of the water column.



Salinity section from the last 50 dives.
The rapid rise in the salinity of the Rockall Trough over the last 30 years may be slowing down.
This could mean that the position of the sub-Polar Front is shifting eastward. Watch this space for developments.

Appendix A

Summary of log file 788

```
version: 66.04
glider: 156
mission: 1
dive: 788
start: 3 7 110 16 0 34
data:
$ID,156
$MISSION,1
$DIVE,788
$D_SURF,2
$D_FLARE,3
$D_TGT,990
$D_ABORT,1050
$D_NO_BLEED,100
$D_FINISH,10
$D_PITCH,0
$D_SAFE,0
$D_CALL,0
$SURFACE_URGENCY,0
$SURFACE_URGENCY_TRY,0
$SURFACE_URGENCY_FORCE,0
$T_DIVE,500
$T_MISSION,530
$T_ABORT,720
$T_TURN,225
$T_TURN_SAMPINT,5
$T_NO_W,120
$USE_BATHY,1
$USE_ICE,-1
$ICE_FREEZE_MARGIN,0.30000001
$D_OFFGRID,990
$T_WATCHDOG,10
$RELAUNCH,1
$APOGEE_PITCH,-5
$MAX_BUOY,100
$COURSE_BIAS,0
$GLIDE_SLOPE,30
$SPEED_FACTOR,1
$RHO,1.0276999
$MASS,51786
$NAV_MODE,3
$FERRY_MAX,45
$KALMAN_USE,2
$HD_A,0.003
$HD_B,0.0099999998
$HD_C,9.9999997e-06
$HEADING,-1
$ESCAPE_HEADING,100
$ESCAPE_HEADING_DELTA,10
$FIX_MISSING_TIMEOUT,0
$TGT_DEFAULT_LAT,5630.2998
$TGT_DEFAULT_LON,-535.5
$TGT_AUTO_DEFAULT,0
$SM_CC,250
$N_FILEKB,4
$FILEMGR,0
$CALL_NDIVES,1
$COMM_SEQ,0
$KERMIT,0
$N_NOCOMM,2
$N_NOSURFACE,0
$UPLOAD_DIVES_MAX,-1
$CALL_TRIES,4
$CALL_WAIT,60
$CAPUPLOAD,0
$CAPMAXSIZE,100000
$HEAPDBG,0
```

```
$T_GPS,15
$N_GPS,20
$T_GPS_ALMANAC,0
$T_GPS_CHARGE,-314932.91
$T_RSLEEP,3
$RAFOS_PEAK_OFFSET,1.5
$RAFOS_CORR_THRESH,60
$RAFOS_HIT_WINDOW,3600
$PITCH_MIN,46
$PITCH_MAX,4003
$C_PITCH,2788
$PITCH_DBAND,0.1
$PITCH_CNV,0.003125763
$P_OVSHOOT,0.039999999
$PITCH_GAIN,28
$PITCH_TIMEOUT,17
$PITCH_AD_RATE,160
$PITCH_MAXERRORS,1
$PITCH_ADJ_GAIN,0
$PITCH_ADJ_DBAND,0
$ROLL_MIN,169
$ROLL_MAX,3842
$ROLL_DEG,40
$C_ROLL_DIVE,2300
$C_ROLL_CLIMB,2120
$HEAD_ERRBAND,10
$ROLL_CNV,0.028270001
$ROLL_TIMEOUT,15
$R_PORT_OVSHOOT,31
$R_STBD_OVSHOOT,27
$ROLL_AD_RATE,400
$ROLL_MAXERRORS,1
$ROLL_ADJ_GAIN,1
$ROLL_ADJ_DBAND,0.029999999
$VBD_MIN,470
$VBD_MAX,3960
$C_VBD,2811
$VBD_DBAND,2
$VBD_CNV,-0.24529999
$VBD_TIMEOUT,720
$PITCH_VBD_SHIFT,0.0012300001
$VBD_PUMP_AD_RATE_SURFACE,5
$VBD_PUMP_AD_RATE_APOGEE,4
$VBD_BLEED_AD_RATE,8
$UNCOM_BLEED,50
$VBD_MAXERRORS,1
$CF8_MAXERRORS,20
$AH0_24V,147
$AH0_10V,112
$PHONE_SUPPLY,2
$PRESSURE_YINT,-16.28265
$PRESSURE_SLOPE,0.0001145783
$AD7714Ch0Gain,128
$TCM_PITCH_OFFSET,0
$TCM_ROLL_OFFSET,0
$COMPASS_USE,0
$ALTIM_BOTTOM_PING_RANGE,0
$ALTIM_TOP_PING_RANGE,0
$ALTIM_BOTTOM_TURN_MARGIN,15
$ALTIM_TOP_TURN_MARGIN,0
$ALTIM_TOP_MIN_OBSTACLE,1
$ALTIM_PING_DEPTH,300
$ALTIM_PING_DELTA,20
$ALTIM_FREQUENCY,13
$ALTIM_PULSE,3
$ALTIM_SENSITIVITY,3
$XPDR_VALID,0
$XPDR_INHIBIT,90
$INT_PRESSURE_SLOPE,0.0097660003
$INT_PRESSURE_YINT,0
$DEEPGLIDER,0
$DEEPGLIDERMB,0
$MOTHERBOARD,4
$DEVICE1,2
$DEVICE2,20
```

```
$DEVICE3,35
$DEVICE4,-1
$DEVICE5,-1
$DEVICE6,-1
$SMARTS,0
$SMARTDEVICE1,-1
$SMARTDEVICE2,-1
$COMPASS_DEVICE,33
$COMPASS2_DEVICE,-1
$PHONE_DEVICE,48
$GPS_DEVICE,32
$RAFOS_DEVICE,-1
$XPDR_DEVICE,24
$SIM_W,0
$SIM_PITCH,0
$SEABIRD_T_G,0.0043895515
$SEABIRD_T_H,0.00064076902
$SEABIRD_T_I,2.6836891e-05
$SEABIRD_T_J,3.0528029e-06
$SEABIRD_C_G,-10.163977
$SEABIRD_C_H,1.1456759
$SEABIRD_C_I,-0.001231113
$SEABIRD_C_J,0.00018464784
$GPS1,154837,5637.816,-939.645,33,1.2,33,-7.9
$_CALLS,2
$_XMS_NAKs,7
$_XMS_TOUTs,1
$_SM_DEPTHo,2.44
$_SM_ANGLEo,-69.7
$GPS2,160025,5637.912,-939.735,11,1.6,17,-7.9
$SPEED_LIMITS,0.114,0.188
$TGT_NAME,HEBRID
$TGT_LATLONG,5627.500,-1023.200
$TGT_RADIUS,5000.000
$KALMAN_CONTROL,-0.027,0.186
$KALMAN_X,79642.9,-305.7,-1928.9,-63586.3,18605.5
$KALMAN_Y,-106027.8,-50.3,1515.0,108682.7,-11627.8
$MHEAD_RNG_PITCHd_Wd,254.5,48478,-14.7,-6.600
$D_GRID,1597
$GCHEAD,st_secs,pitch_ctl,vbd_ctl,depth,ob_vertv,data_pts,end_secs,pitch_secs,roll_secs,vbd_se
cs,vbd_i,gcphase,pitch_i,roll_i,pitch_ad,roll_ad,vbd_ad
$STATE,10,end surface,CONTROL_FINISHED_OK
$STATE,10,begin dive
$GC,15,-0.64,-97.3,0.0,0.0,0,55,0.00,0.00,-38.62,0.000,2,0.000,0.000,28,2307,2529
$GC,59,-0.64,-97.3,3.3,-2.4,6,103,10.32,2.62,-27.20,0.000,4,0.226,0.064,2571,889,3207
:
:
:
$GC,12169,-0.64,-97.3,983.1,-6.6,747,12170,0.00,0.00,0.00,0.000,6,0.000,0.000,2573,1954,3209
$STATE,12285,end dive,TARGET_DEPTH_EXCEEDED
$STATE,12285,begin apogee
$GC,12295,-0.18,0.0,991.8,6.9,749,12383,0.47,0.00,86.65,1.243,6,0.116,0.000,2726,2130,2812
$STATE,12383,end apogee,CONTROL_FINISHED_OK
$STATE,12384,begin climb
$GC,12388,0.64,97.3,994.1,0.0,750,12482,0.75,2.75,86.90,1.215,4,0.063,0.059,3007,718,2412
$GC,12521,0.68,128.9,992.5,5.1,752,12555,0.00,2.58,29.27,1.166,6,0.000,0.044,3007,2117,2285
:
:
:
$GC,23538,0.70,141.5,3.4,11.0,1440,23544,0.00,0.00,0.00,0.000,6,0.000,0.000,3038,2241,2234
$STATE,23551,end climb,SURFACE_DEPTH_REACHED
$STATE,23551,begin surface coast
$FINISH,1.7,1.027298
$STATE,23567,end surface coast,CONTROL_FINISHED_OK
$STATE,23568,begin surface
$SM_CCo,23590,99.75,0.517,11,0,1790,250.21
$SM_GC,2.41,0.00,0.00,99.75,0.000,0.000,0.517,11,2310,1790,-8.68,0.28,250.21
$IRIDIUM_FIX,5617.48,-941.23,010699,161644
$TT8_MAMPS,0.052923
$HUMID,1946
$INTERNAL_PRESSURE,9.83436
$TCM_TEMP,20.20
$XPDR_PINGS,10
$24V_AH,22.7,93.046
$10V_AH,10.2,63.139
```

$DEVICES,Pitch_motor,Roll_motor,VBD_pump_during_apogee,VBD_pump_during_surface,VBD_valve,Iridi
um_during_init,Iridium_during_connect,Iridium_during_xfer,Transponder_ping,Mmodem_TX,Mmodem_RX
,GPS,TT8,LPSleep,TT8_Active,TT8_Sampling,TT8_CF8,TT8_Kalman,Analog_circuits,GPS_charging,Compa
ss,RAFOS,Transponder,Compass2
$DEVICE_SECS,22.425,478.025,213.025,99.750,0.000,60.911,74.802,303.779,11.250,0.000,0.000,21.1
20,0.000,17730.451,808.794,4256.120,1620.336,0.000,2676.536,0.000,3363.714,0.000,62.415,0.000
$DEVICE_MAMPS,226.265,79.768,1242.540,516.958,0.000,103.000,160.000,223.000,420.000,0.000,0.00
0,50.000,19.800,2.190,19.800,39.800,45.800,81.800,12.000,0.000,8.000,0.000,30.000,0.000
$SENSORS,SBE_CT,SBE_O2,WL_BB2F,nil,nil,nil,nil,nil
$SENSOR_SECS,980.130,1037.144,413.411,0.000,0.000,0.000,0.000,0.000
$SENSOR_MAMPS,24.000,19.000,105.000,0.000,0.000,0.000,0.000,0.000
$DATA_FILE_SIZE,72501,1446
$CAP_FILE_SIZE,300864,0
$CFSIZE,260165632,204406784
$ERRORS,0,0,0,0,0,0,0,0,0,0,0,0,0,11,0
$CURRENT,0.045,291.1,1
$GPS,070310,223731,5637.087,-944.955,43,1.2,43,-7.9

Appendix B

Investigations into thermal mass corrections

B.1 Introduction

The Temperature-Conductivity sensor on Talisker during Mission 1 was an unpumped Sea-Bird system that is based on the SBE41 that is used on Argo floats and is a standard configuration for a Seaglider. The sensor is mounted towards the rear of the glider on the upper side above the wing (Figs 1 and 2).

Figure 1. The Sea-Bird sensors. The temperature-conductivity sensor package is directly above the wing. It has protective end caps in place.

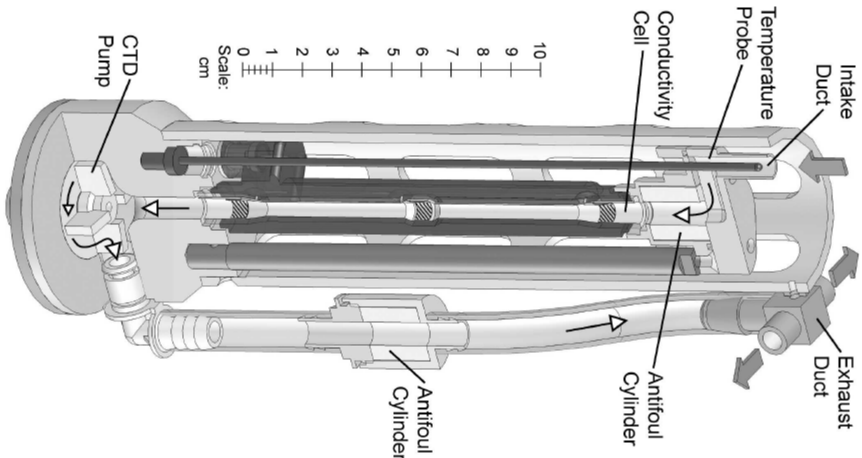
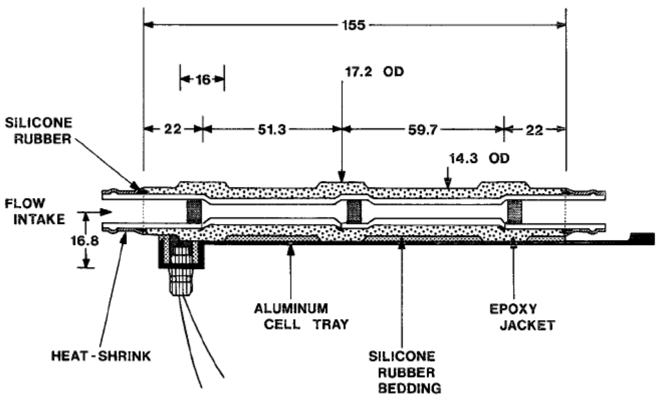


Figure 2. A cutaway, perspective, scaled rendering of the Sea-Bird electronics Inc model SBE 41 CTD instrument. (Johnson *et al.*, 2007. The exhaust pipe is not present on the Seaglider

As part of the processing of the conductivity observations by the basestation, the thermal mass of the temperature-conductivity package is accounted for by adjusting the observed temperature before calculating salinity. In this way it is hoped that spikes in salinity observations during passage through sharp pycnoclines will be reduced. The principle of this adjustment is the same as that used with the pumped SBE9 system that is normally mounted on a ship's CTD frame. The main difference between the ship operation and that of the Seaglider is that the SBE9 on the ship's CTD is pumped at a fixed rate whilst the SBE9 is plunged at up to 1 m s^{-1}, whilst a glider SBE41 normally descends at a rate of about 0.1 m s^{-1}. Hence the fact that the glider SBE41 cell is unpumped is countered by the fact that it will encounter much slower changes in temperature.

SBE-4 CONDUCTIVITY CELL



• ALL MEASUREMENTS ARE IN MM

FIG. 1b. The glass cell mounted into its aluminum tray. Silicon rubber bonds the epoxy jacket, and hence the glass cell, to the tray. This assembly is mounted to the pressure case holding the SBE electronics.

Figure 2. The cross section through the SBE4 conductivity cell (Lueck, 1990)

B.2 The built-in basestation correction

Thermal mass considerations may still be important, and the Seaglider basestation corrects for thermal mass using the following algorithm (MakeDiveProfiles.py, line 1232, see Appendix):

$$\theta_c = \theta_r \tau_\theta \frac{d\theta_r}{dt},$$

where τ_θ = 0.6 s is a time constant for the temperature sensor, and

$$C_c = C_r + \tau_c \frac{dC_r}{dt}$$

where $$\tau_c = \frac{1}{\left(0.01 + v^2 / 5.97\right)}$$

Here θ_c is the corrected temperature to be used in the salinity calculation; θ_r is the raw (original) temperature reading coincident with the conductivity measurement; τ_c is a time constant for the conductivity sensor and v is the total velocity of the glider through the water in decimetres s^{-1}. For typical glider speed of 25 cm s^{-1} τ_c is about 1 s.

No justification is given for the values of τ_c and τ_θ, but the approach seems similar to that discussed in the literature in respect to standard CTD and Argo float applications (e.g. Johnson *et al.*, 2007; Lueck, 1990; Lueck and Picklo, 1990; Morison *et al.*, 1994).

B.3 An investigation of mission 1

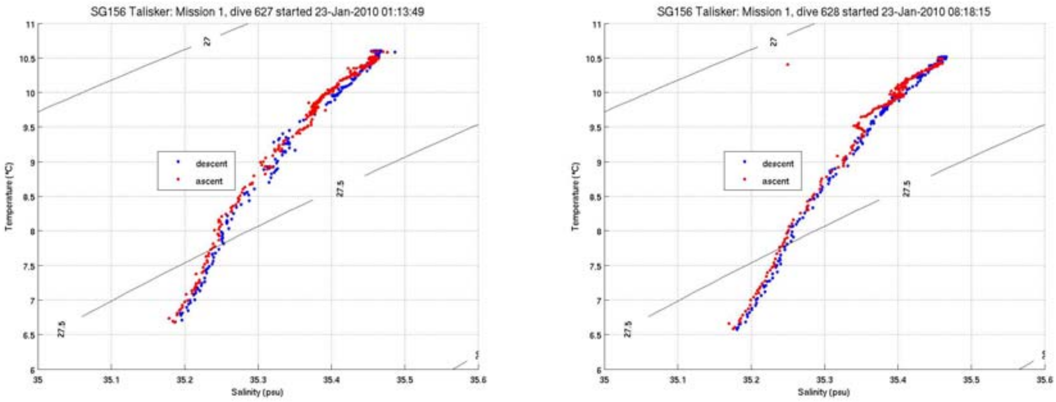


Figure 3. Typical θS plots from dives 627 and 628 that might be taken to imply that the down casts produce a different curve to up casts (particularly in the small but significant differences below 9° C).

In investigation into potential errors in salinity sampling, initially suggested that some further correction might be necessary. Many θS curves produced up-casts that were marginally different to the preceding down-casts (see Fig. 3). To investigate whether the differences in θS could be corrected in some simple way matlab routines sg_thermal_mass.m and sg_thermal_mass_investigations_3.m have been created (with some supporting routines). These routines applied corrections to the reported temperatures along the lines of

$$\theta_T(t) = -b \times \theta_T(t - \Delta t) + a \times (\theta(t) - \theta(t - \Delta t))$$

where θ is the measured temperature; θ_T is the true temperature; t is the present time step and Δt the sample interval (to which the original data have been interpolated);

$$a = \frac{\alpha \times 4\tau/\Delta t}{(1 + 4\tau/\Delta t)};$$

and $$b = 1 - 2a/\alpha$$

Following the arguments in the papers referred to in Section 2, α is the initial error in the measured temperature; and τ is a time constant associated with the thermal mass of the conductivity cell.

Typical ranges in the values of α and τ were investigated to see if the standard deviation in the difference in salinity between up- and down-casts (interpolated onto a regular θ grid) could be consistently minimised. Both the corrected basestation salinities and uncorrected ones were investigated, but the results were ambiguous and did not indicate that any improvement could be made in this way.

As an additional test the measured temperatures were lagged by small amounts Δn (i.e. $\theta(n) = \theta(n - \Delta n)$) to see if there was a difference in the observation time due to the physical offset of the thermistor from the conductivity cell. For dives 601 to 699 it appeared that Δn = 3 s significantly reduced the standard deviation between coincident up- and down-casts. However, such a large offset is inconsistent with the typical values for Argo floats (Δn ~ 0.07 s) and suggests that the differences between the up- and down-casts may be real.

B.4 Conclusion

So - back to the drawing board. On closer investigation it is apparent that there was a gradual change in the θS properties within the Trough (furthermore, dives 601 to 699 included an investigation of an eddy). Thus minimising that standard deviation of salinity differences by lagging the temperature measurement time introduces a bias and can not be justified. Furthermore it is possible to find dives where there is no appreciable difference in the up- and down-casts, particularly below 9° C (see e.g. dive 574, Fig. 4).

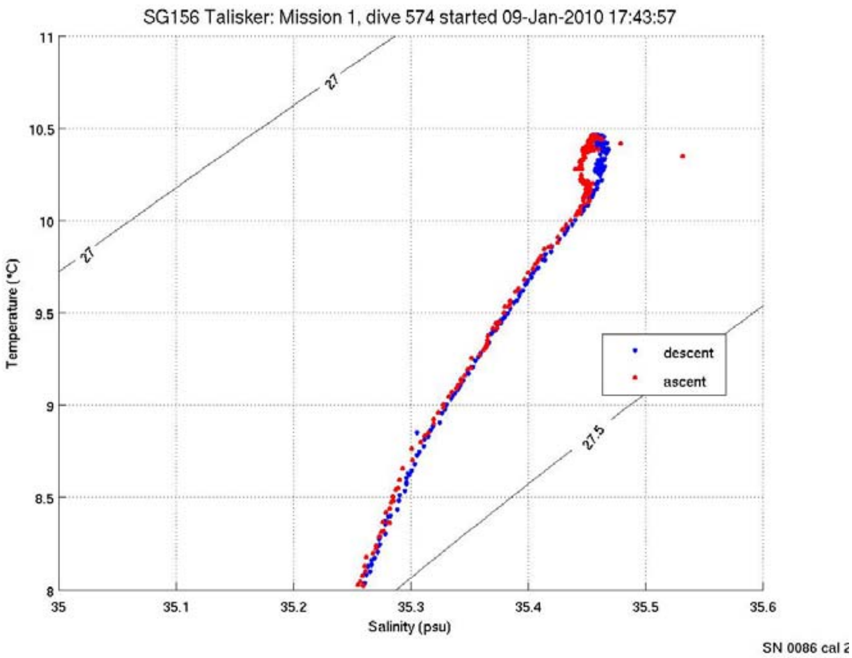


Figure 4. Dive 574 which shows very close correlation in θS between the up- and the down-casts.

In conclusion, since it has not been possible to determine the precise internal configuration of the Sea-Bird temperature / conductivity package on board Talisker there is no justification for correcting the salinities and temperatures computed by the basestation.

B.5 References

Johnson, C.J., Toole, J.M., Larsen, N.G., 2007. Sensor Corrections for Sea-Bird SBE-41CP and SBE-41 CTDs. Journal of Atmospheric and Oceanic Technology 24, 1117-1130, DOI:10.1175/JTECH2016.1.

Lueck, R.G., 1990. Thermal inertia of conductivitiy cells: Theory. Journal of Atmospheric and Oceanic Technology 7, 741-755

Lueck, R.G., Picklo, J.J., 1990. Thermal inertial of conductivity cells: observations with a Sea-Bird cell. Journal of Atmospheric and Oceanic Technology 7, 756-768

Morison, J., Andersen, R., Larson, N., d'Asaro, E., Boyd, T., 1994. The correction for themal-lag effects in Sea-Bird CTD data. Journal of Atmospheric and Oceanic Technology 11, 1151-1164

Annex B.1

Basestation code for correcting conductivity.

```
starting at line 952

    base_log.debug("Check for reasonable sg_calib_constants.m file")
    base_log.debug("id_str = %s, mission_title = %s" % (id_str, mission_title))

    # C/T constants
    calibcomm = calib_consts['calibcomm']
    t_g = calib_consts['t_g']
    t_h = calib_consts['t_h']
    t_i = calib_consts['t_i']
    t_j = calib_consts['t_j']

    c_g = calib_consts['c_g']
    c_h = calib_consts['c_h']
    c_i = calib_consts['c_i']
    c_j = calib_consts['c_j']

    cpcor = calib_consts['cpcor']
    ctcor = calib_consts['ctcor']

    temp_freq_min = None
    temp_freq_max = None
    cond_freq_min = None
    cond_freq_max = None

    try:
        temp_freq_min = calib_consts['sbe_temp_freq_min'] * 1000.0
        temp_freq_max = calib_consts['sbe_temp_freq_max'] * 1000.0
        cond_freq_min = calib_consts['sbe_cond_freq_min'] * 1000.0
        cond_freq_max = calib_consts['sbe_cond_freq_max'] * 1000.0
    except KeyError:
        base_log.warning("Temp/cond limits for C/T not found in %s - no range checking applied" %
sg_calib_file_name)
```

starting at line 1232:

```
    # Now that we have revised estimates of glider speed through the
    # water (total_speed_cm_s_v), horizontal speed (horizontal_speed_cm_s_v), and
    # glide angle (glide_angle_deg_v), we can take on the conversion of
    # temperature and conductivity frequency to temperature and conductivity,
    # and apply first-order lag corrections to both.

    # Temperature calculation from SBE3F data sheet
    # Formula appropriate for reading from p*.eng

    tempFreq_v = eng_f.get_col_filtered('tempFreq', bad_samples)
    LogTempFreqScaled_v = zeros(num_rows, float)
    TempC_v = zeros(num_rows, float)

    for i in range(num_rows):
        if(tempFreq_v[i] == nan):
            base_log.error("tempFreq_v[%d] = nan - data from syntheic? Bailing out of make_dive_profile" %
tempFreq_v[i])
            return 1
        LogTempFreqScaled_v[i] = math.log(f0/tempFreq_v[i])
        TempC_v[i] = (1.0/(t_g + (t_h + (t_i +
t_j*LogTempFreqScaled_v[i])*LogTempFreqScaled_v[i])*LogTempFreqScaled_v[i])) - 273.15

    # Conductivity calculation from SBE4 data sheet
    # Formula appropriate for reading from p*.eng

    CondFreqHz_v = eng_f.get_col_filtered('condFreq', bad_samples) / f0
    Cond_v = (c_g + (c_h + (c_i + c_j*CondFreqHz_v)*CondFreqHz_v)*CondFreqHz_v*CondFreqHz_v)/(10.0*(1.0 +
ctcor*TempC_v + cpcor*eng_f.get_col_filtered('depth', bad_samples)/100.))

    # Compute dT/dt and dC/dt

    dTemp_dt_v = ctr_1st_diff(TempC_v, eng_f.get_col_filtered('elaps_t', bad_samples))
    dCont_dt_v = ctr_1st_diff(Cond_v,  eng_f.get_col_filtered('elaps_t', bad_samples))

    # Apply first-order lag corrections, based on specified tau's for T and C
```

```
tau_Temp = 0.6
tau_Cond_v = zeros(num_rows, float)
for i in range(num_rows):
    tau_Cond_v[i] = 1.0/(0.01 + (total_speed_cm_s_v[i]/10.)*(total_speed_cm_s_v[i]/10.)/5.97)

TempC_Cor_v = TempC_v + tau_Temp*dTemp_dt_v
Cond_Cor_v  =  Cond_v + tau_Cond_v*dCont_dt_v
```

Appendix C

An analysis of DO levels from the Sea-Bird SBE43 oxygen sensor

C.1 Introduction

The Dissolved Oxygen (DO) sensor on Talisker during Mission 1 was an unpumped Sea-Bird SBE43 which is a standard configuration for a Seaglider, and the one recommended by Seaglider Fabrication when the order was placed in 2008. The advantages of the sensor is that it has a fast response rate that is commensurate with the other sensors on the glider, but the disadvantage is that since it is not pumped the observations are not guaranteed by Sea-Bird. The sensor is mounted towards the rear of the glider on the upper side and behind the Sea-Bird temperature and salinity sensor package (Fig. 1).

Figure 1. The Sea-Bird sensors. The temperature and salinity sensor package is directly above the wing and the DO sensor is in the short white tube slightly behind the wing. Both sensors packages have protective end caps in place.

C.2 CTD observations in the Rockall Trough from CD176

The RRS Charles Darwin Ellett Line cruise CD176 took place between 6th and 18th October 2005. Calibrated CTD measurements using a pumped SBE43 were made at roughly the same time of year as Mission 1, and the CTD was calibrated using Winkler titrations (see Sherwin et al, 2005). The mean DO saturation in the top 50 m from Stations E, F, L, M, and Q in the Rockall Trough ranged between 96.9 and 97.6%

C.3 The recorded observations

Throughout Mission 1 the recorded DO values were always about 1 ml/l less than saturation in the surface layers. Figure 1 is a typical example. The observations were made in the winter surface mixed layer where there is no stratification and where one expects to observe close to saturated values.

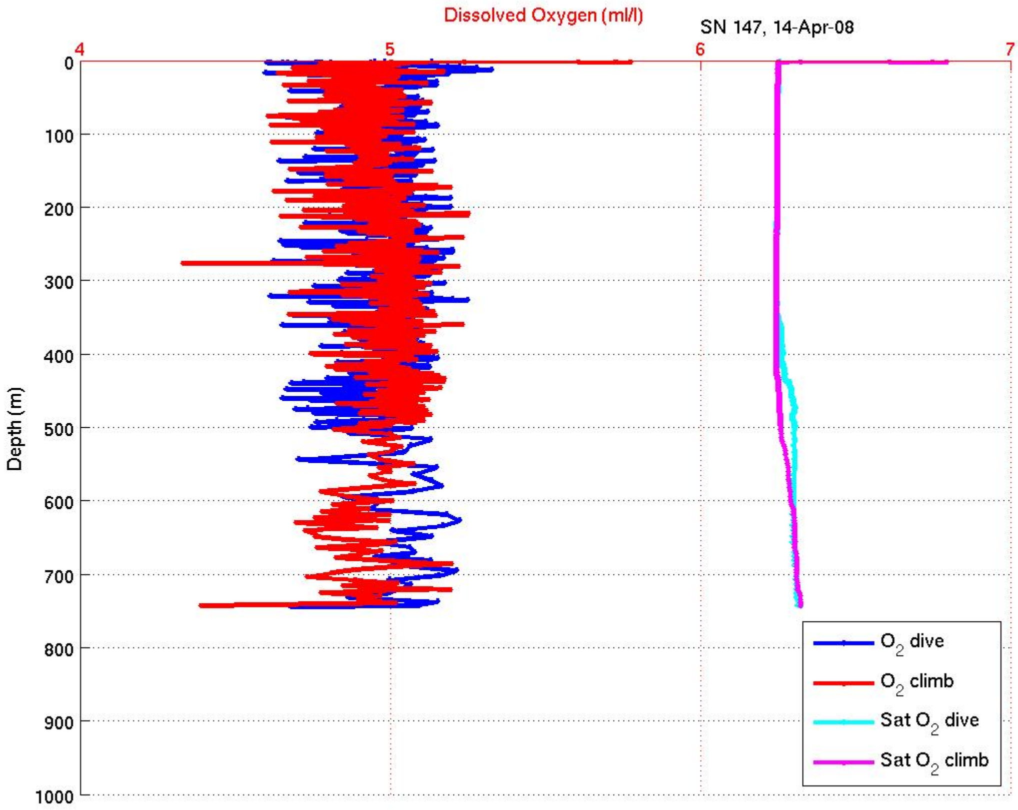


Figure 2. DO values calculated by the basestation for dive 782 on 06 March 2010. Note: the units are in ml/l.

The observed surface values in the Rockall Trough in winter 2009/2010 were ~ 5 ml/l compared with about 6.3 ml/m for the saturated values. The mean saturation in the top 50 m for typical dives 269, 285, 298, 314, 331 (23 Oct to 11 Nov) ranged from 83.5% to 88%, significantly less than the 97% saturations observed during CD176.

One possible explanation for this discrepancy, that has been investigated in detail, is that the observed DO values are wrongly calculated. However, inspection of the code and other tests, not detailed here, has indicated that MakeDiveProfiles.py uses the correct values and algorithm to compute both the saturated and the observed values (Appendix 2).

C.4 Post cruise comparison with SAMS CTD system

Talisker unexpectedly had to be recovered from the *NLB Pole Star* at the end of her mission, and consequently no independent *in situ* DO readings were made. In addition, the only independent *in situ* observations were made on conductivity and temperature at the start of the mission and are therefore not relevant. However, as a test we deployed Talisker tied on to a SAMS Sea-Bird CTD frame from *Calanus* in local waters at the end of the cruise. This system can not be considered identical to what happens to the sensors when water is flowing through and around them during a dive, but nevertheless it makes for an interesting comparison.

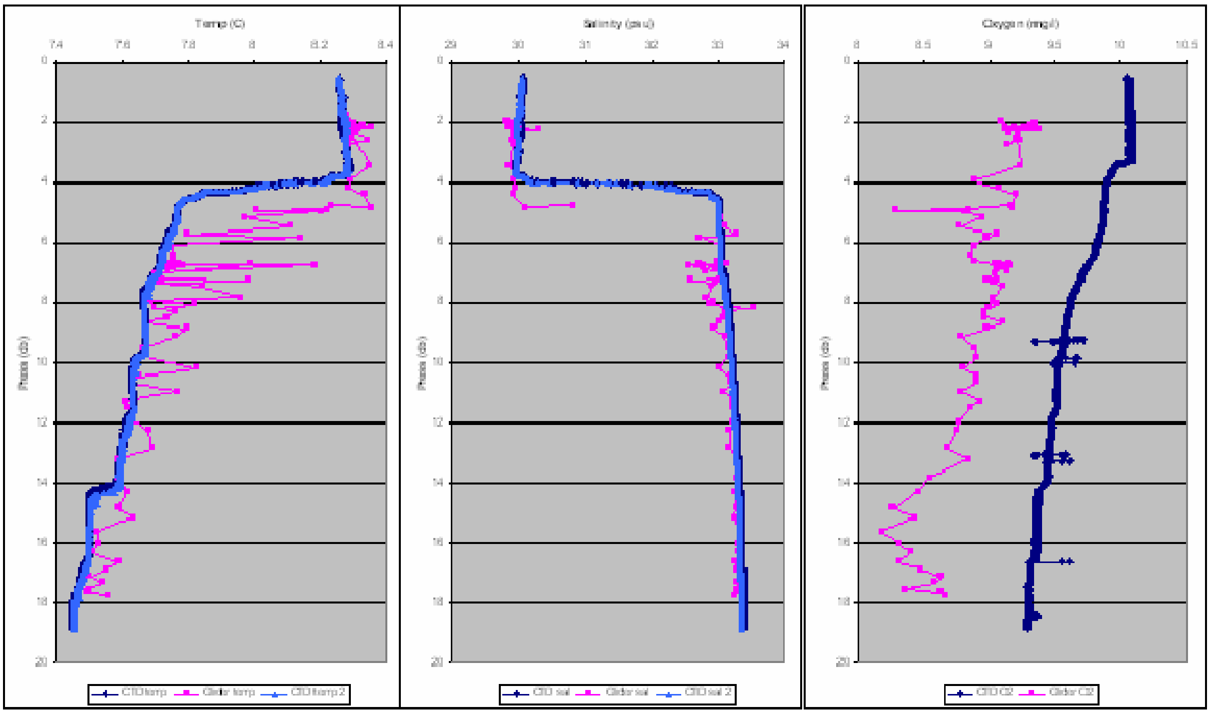


Figure 3. Observed temperature, salinity and DO values from a Sea-Bird SBE43 (blue) and SG156 (purple). Note: the units for DO are mg/l.

The recorded glider values were about 1 mg/l (or 0.6 ml/l) less than those observed by the CTD (Fig. 3). However, there were no independent water samples for titration calibration purposes at this time so we are not totally certain of the absolute values. Temperature and salinity profiles from the two systems were similar, although the temperature values were surprisingly noisy. This noise may be due to the sensor being used in an unconventional way since we do not see it in the dive traces.

C.5 Calibrations

The SBE43F calibration sheets from before and after the mission are attached included in Appendix 3. They reveal that the shift in calibration during the mission was very small. It should be noted that for the original post cruise processing one of the calibration constants that was used in sg_calib_consts.m file was wrong by a factor of 10. However, correcting this value made very little difference to the measured oxygens.

C.6 Conclusion

All our evidence points to a problem with the unpumped SBE43 DO sensor when mounted on a Seaglider. To this can be added the comments from Eric D'Asaro (see Appendix 1), the decision by Nicholson *et al.*, 2008 to use Optode data in preference to the SBE43 when both were installed on their Seaglider, and the fact that Perry *et al.*, 2008 had to offset their SBE43 data to match 100% saturation at the surface.

When all these factors are taken into account it's seems pretty clear that we need to put an Aanderaa Optode on Talisker and run it in parallel with the SBE43. Two types of Optode are available, the 4330 and the 4330F. The latter has a faster response time and is hence more accurate, but Aanderaa state that it is only stable for about a month and since it is more delicate than the 4330 it should not be used on long missions.

C.7 References

Nicholson, D., Emerson, S., Eriksen, C.C., 2008. Net community production in the deep euphotic zone of the subtropical North Pacific gyre from glider surveys. Limnology a nd Oceanography 53 (5), 2226-2236

Perry, M.J., Sackmann, B.S., Eriksen, C.C., Lee, C.M., 2008. Seaglider observations of blooms and subsurface chlorophyll maxima off the Washington coast. Limnology and Oceanography 53 (5), 2169-2179

Annex C.1

Correspondence with Seaglider Fabrication

The essential correspondence between SAMS and Fritz Stahr at Seaglider about the DO sensor starting with an email by TJS dated 7th Sept 2010:

Dear Fritz

2. DO calculation on the basestation
I've been trying to get to the bottom of our DO calculation problem, but I'm beginning to realise that I'll have to become an expert in both python code and Seaglider's implementation of it before I can get to the bottom of this. I'm convinced that there is probably a software bug in the basestation code that won't be simply resolved with a recalibration of the sensor, unless the sensor was rubbish in the first place of course. The offset is simply too big. Could you look at my little report and either suggest something else we should do or ask someone at your end to have a look at it.

cheers

Toby

Fritz's reply and other correspondence is inserted below:

>> From: Eric D'Asaro <dasaro@apl.washington.edu>
>> Date: September 8, 2010 6:56:00 PM PDT
>> To: Fritz Stahr <stahr@ocean.washington.edu>
>> Subject: Re: DO observations
>>
>> A few quick comments:
>> I agree that the reported offset is indeed very large and renders
>> the computed oxygen quite useless.
>> We commonly see offsets between calibrated SBE43 and Winklers, but
>> nowhere near that large. However, this is for pumped SBE-43
>> units. The SBE43 doesn't work very well when it's not pumped, so I
>> haven't even looked at the NAB oxygen data from those units in NAB.
>>
>> The very high noise in the oxygen data is also troubling. It should
>> be much less. There might be something wrong here. You might ask
>> Steve Emerson or Charlie if they think that the noise is excessive.
>> You also might look to see if this noise is in the raw numbers or
>> was induced by some processing, temperature or salinity error.
>>
>> For reference, using pumped, in-situ calibrated SBE-43s I can get
>> accuracies of 2 uMol/kg and precisions of well better than 1 uMol/
>> kg. This takes considerable work.
>>
+++++

>>>> Fritz Stahr <stahr@ocean.washington.edu> 10/09/2010 22:03 >>>
> Toby & Estelle,
>
> Below are some comments from my colleague Eric D'Asaro, a physical
> oceanographer at APL who was co-PI of the 2008 North Atlantic Bloom
> experiment (NAB - see http://adsabs.harvard.edu/abs/2008AGUFMOS24A..
> 08D for synopsis). As he points out, the un-pumped version of the
> SBE43 on Seagliders isn't necessarily great, and he has no experience
> processing that yet for the 4 Seagliders in NAB. But some people do
> get decent results out of of those - see for example Charlie's data
> from the Washington coast at http://iop.apl.washington.edu/seaglider/dives.php?glider=14&mission=WA_coast_Mar07
> Regardless of whether it's pumped or not, having bottle-data
> (titrations) to provide comparison is really important.
>
> I agree with Eric that the spikiness/noise is troubling. I assume
> you've already attempted to remove any temp and conductivity spikes
> that could influence DO as T & S are in the equation. And, I assume
> you've eliminated out-laying data points more than 3-sigma beyond mean

> (de-spiking). It could be that this is from a turbulent flow over that
> part of the glider so the sensor plenum is not being fully flushed -
> that's been observed in flume-tank testing of a small-scale model of
> plain aft fairing. The opening in the plenum is very large so it
> should get decent flow through it, but if in a big recirculation cell
> over the aft fairing may not (would expect to manifest itself mostly
> as depth lag in signal).
>
> Unfortunately I'm not sure how to make your oxygen data "fit for
> purpose" other than to put the offset you found between it and your
> CTD cast in the Loche on top of all the data. Alternately, you can
> wait to get the post-cruise cal from Sea-Bird and re-calculate it with
> those parameters to see if it's closer to your CTD and surface
> saturation. If this data is critical to your missions (i.e., DO is the
> primary parameter of interest to users) then having wet-chemistry
> comparisons is also critical. On the Seaglider, there are other things
> to try, such as
>
> 1) moving the sensor further up into the free-stream at the cost of
> more drag so less deployment time (easy to do by remounting the
> sensor)
> 2) putting a pumped system on it which is addressed through a generic
> serial port - but that will take some development to create a driver
> that can turn the pump and sensor on long enough before taking a
> reading to have a valid sample in the tube. (not a quick fix and also
> reduces deployment time due to energy to pump)
>
> I hope this helps...
>
> - Fritz
+++++

On Sep 14, 2010, at 7:01 AM, Toby Sherwin wrote:

> Hi Fritz
>
> Thank you for getting some feedback from Eric and for your other
> thoughts. I'd been thinking about applying your idea of shifting
> the O2 readings to match DO saturation at the surface - this is what
> Perry et al (2008), Limnol & Oceanog did that enabled them to get a
> story out of their data. That's a bit of a botch in my opinion,
> since we don't know whether the difference has a trend in it.
>
> Although we didn't do any in situ calibrations with water samples,
> we've been back to look at measurements that we've made from ships
> in winter in the Rockall Trough in earlier years and we know that
> the SBE43 should be giving values that are closer to 100% saturation
> at the surface. (i.e. better than 95% sat rather than the 85% that
> we see)
>
> But then equally Nicholson et al (2008), Limnol & Oceanog got what
> seems like a pretty good calibration from the Optode. (Their paper
> also mention the SBE43 at the beginning, but then it seems to slip
> from the story, so I think all their plots etc use an Optode).
> Although I agree that Charlie's surface DO readings look reasonable,
> I'm still not convinced that our sensor is giving valid readings.
>
> You also refer to the noise. We've not looked into that at all, and
> although I agree that it looks bad I wasn't so worried about that
> because it could always be smoothed out. But equally I don't think
> that it's anything to do with temperature or salinity fluctuations
> since the water column at the end of winter is isothermal and
> isohaline over large depths. I think as you imply there's something
> not quite right about using an unpumped SBE43 and more work needs to
> be done by either Sea-Bird or yourselves to explain the low values
> and the noise that we see.
>
> Obviously we must wait until we get the calibration data back from
> Sea-Bird, but ...
>
> DO measurements are important to us, so I'd like to explore the

> implications of swopping to an Optode for Talisker. Is it feasible
> and what would the cost be? Would there be any point/value/
> difficulties in running both Optode and SBE43 together? I'm
> thinking for scientific reasons of delaying our next mission until
> the New year in order to catch the spring bloom so time is not so
> important.
>
> Anyway, if we are going to do anything about it now's the time while
> Talisker is in Seattle.
>
> cheers
>
> Toby
>
+++++

Toby,

You're welcome and I think that your plan to set to saturation at surface may be the best you can do. Nicholson's Seagliders were actually equipped with both a SBE43 and an Optode, but Steve Emerson (his advisor) decided early on that he much preferred the Optode data - not exactly clear why. Those Seagliders were owned and piloted by Charlie Eriksen in a joint project with Steve. Craig Lee (UW) and Dave Karl (Univ of Hawaii) have also equipped many Seagliders with both Optodes and SBE43s so it's actually a standard configuration to carry both (easy integration too). All Optodes are externally mounted so it would be easy to add to yours, though would introduce a slightly off-axis drag element because your aft-fairing currently has just the one hole on centerline for the SBE43. We could bring the SBE 43 outside the fairing too to get it more in the free-stream, but it will add much more drag as well. If you're willing to invest in a new aft-fairing with panels, we can easily mount them side-by-side , and provide panels for just one or the other - part of the reason for the panel design, plus accessibility to aft-endcap plugs for ease of field switches. But buying a new aft-fairing is much more expensive than just adding the Optode sensor.

As for explaining the spikiness and offset of your first mission's data, Sea-Bird won't help you because it's un-pumped and they don't like to deal with anything in that realm. Their philosophy with all glider instrumentation has been to make the glider manufacturer (us, Webb, Scripps/BlueFin, and now iRobot), who chose the un-pumped design, be responsible to their customers for data explanation, etc. (I've heard that Webb has sent an # of their glider customers to Sea-Bird when they got strange CT data, but they basically say there's not much that can be done - just bad flow through the cell.) So I will try to help you with this data, but if you'd asked me up front what to do to make sure you have good oxygen data from these Seaglider profiles, I would have said to get bottle data at multiple depths while out with a ship to make a curve/points to tie the profiles to (yes, trends with depth are important). I had to do that for my thesis and it's the only thing that made the profile oxygen data valuable, which was taken with multiple pumped SBE systems on various vehicles & cages - bottle data is critical to get good absolute #s. You can still do that if you have a time-series of bottle profiles from the area for the same season - may be just as good as tying surface values to saturation for upper part of water column and may give you trend in lower part. Also, I would have recommended purchasing an Optode for your glider and running both it and SBE43 for the glider, though when we built your glider, we had Optode's on some Seagliders flooding and shorting out (not high reliability) so at the time I may not have been very positive about it. Because both oxygen units have flaws, there has not been a conclusive decision by any glider user as to which is best per-se, though some clearly have their favorites (e.g., Optode for Emerson & Nicholson). As pointed out by Eric, the SBE43 is really best pumped though even then having bottle data to force the profiles to is important. Unfortunately, that's not a current option on a Seaglider.

Attached is a quote for an Optode (model 4330, not the "fast-foil") and modifying your fairing to mount to your Seaglider in addition to your SBE43. It might take 8 weeks ARO to get the unit from Aanderaa - we have none on hand. We can also explore modifications to your fairing to get the SBE43 further up into the free-stream. But before doing that it would be good to just de-spike the data in a standard fashion and see how much that cleans it up. Extra mods to your fairing will begin to make it look a bit like a science-project, but we can add covers over open holes. I can't tell you what the extra drag will do for longevity - the longest endurance records we have are 9.6 mo with a single SBE43 mounted just like yours.

Hope this helps...

Regards,
- Fritz

As a result of this correspondence and the investigations described above we decided to purchase an Aanderaa Optode DO sensor to supplement the observations from the SBE43. Fritz wrote on 20 Sept 2010 in reply to our indication to make this order:

Thanks Toby for the note. We'll order it from Aanderaa. One question they'll ask is whether you want a "fast foil" or not. That sensor does not have the teflon coating on the foil so it nominally responds more quickly to gradients (I believe) but also is subject to easier bio-fouling and interference by sunlight. You have to protect it from UV for it's whole life (they actually recommend it always face down in the water column which is inconvenient for launch/recovery of the glider) and it must be kept damp it's whole life. Attached is Aanderaa's product spec sheet on it so you can make some decision. Personally I would recommend the regular 4330.

Thanks,
- Fritz

From: Anders Tengberg <anderste@chem.gu.se>
Date: October 8, 2010 6:26:28 AM PDT
To: "Rieff, Brandon" <Brandon.Rieff@aadi.no>, Karl Kunkle <kkunk54@ocean.washington.edu>
Cc: "richard.butler@itt.com" <richard.butler@itt.com>, Jarle Heltne <jarle.heltne@aadi.no>, Jostein Hovdenes <Jostein.Hovdenes@aadi.no>, "stahr@ocean.washington.edu" <stahr@ocean.washington.edu>
Subject: RE: DO observations

Hi Karl and Brandon,

I am sorry for my delay in replying you back I have been travelling this week.

Concerning the advantages and inconveniences of the fast foil versus the one with the protective black layer it is to some extent summarized in our report from the Baltic Sea in 2008. See especially at the end of the report.

Advantages with using 4330 with fast foil:

- **4 times faster response time**

Inconveniences with using 4330 with fast foil:

- **3 times more noisy**
- **Spiking from directly incoming sun light**
- **Bleaching in sunlight which leads to negative drift, 1-2 hours in the sun is enough to see effects**

For glider and float deployments the potential wetting effect (maximum 2%) will play a role only for the first 12 hours or so of the deployment if the foil was dried out before it was deployed. After that the foil will be kept wet either while in the water or in the damped air just above the sea surface while the glider/float is communicating.

My recommendation:
If the gliders is supposed to be deployed for more than a month and stability of the O2 measurements is of prime importance and at the same time there is a risk that the foil will be exposed for more than 1 hour to direct sunlight I would select the slow foil.

If the prime interest is to have better response time of the O2 readings and the risk of bleaching related drift and the higher noise level is of second importance then you could use fast foil.

Could you not make the glider surface during low light periods of the day?

Is there an interest to measure in air while transmitting data back (see Argo float data in attached Sensors and Systems)?

Best Regards, Anders

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Annex C.2

The Python code that deals with the oxygen sensor:

For information, the MakeDiveProfiles.py code that computes DO in the basestation has the following lines:

```
%
% line 989
    try: # not all gliders have O2 sensors - look first for the SBE_O2
constants
        A = calib_consts['A']
        B = calib_consts['B']
        C = calib_consts['C']
        E = calib_consts['E']
    except KeyError:
        SBE_O2_present = False
        if(eng_f.get_col('O2Freq') != None):
            base_log.error("SBE43 O2 constants not found in %s, but SBE43
data found - skipping SBE43 O2" % sg_calib_file_name)
    else:
        SBE_O2_present = True
%
% line 1339:
    # TODO: Need to deal with both types of SBE-43 Oxygen calibrations --
start with just the A, B, C, E (old?) type
    if(SBE_O2_present):
        Oxygen_v = Soc*(eng_f.get_col_filtered('o2_freq', bad_samples) +
Foffset)*(1.0 + A*TempC_Cor_v + B*TempC_Cor_v*TempC_Cor_v +
C*TempC_Cor_v*TempC_Cor_v*TempC_Cor_v)*(Oxygen_sat_v*exp(E*Pressure_v/TempK
_Cor))
    else:
        Oxygen_v = zeros(num_rows, float)
```

Here the routine ‘calib_consts.py’ essentially interrogates sg_calib_constants,m to determine the DO calibration constants o_a to o_e.

Appendix C.3

Pre and post cruise calibration sheets

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **12/27/2007** Description **SBE-43F DO Sensor**

Job Number: **50085** Customer Name **SEAGLIDER FABRICATION CENTER**

SBE Sensor Information:

Model Number: **43F**

Serial Number: **0147**

Pressure Sensor Information:

Sensor Type: **None**

Sensor Serial Number: **None**

Sensor Rating: **0**

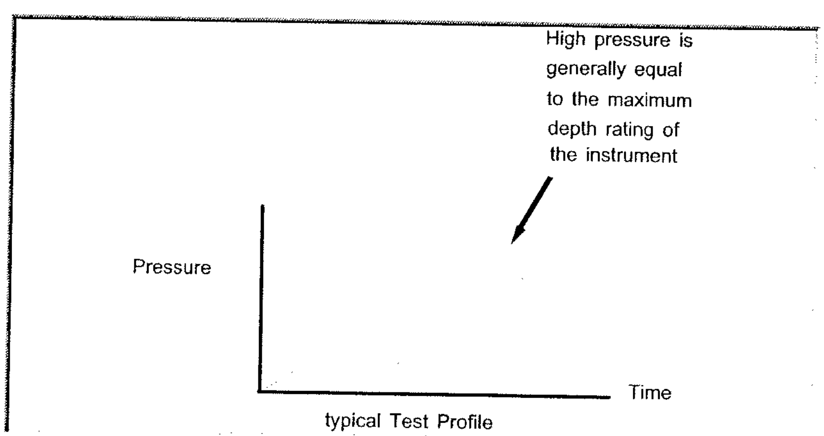
Pressure Test Protocol:

Low Pressure Test: **50** PSI Held For **15** Minutes

High Pressure Test: **850** PSI Held For **30** Minutes

Passed Test: ☑

Tested By: MJD



typical Test Profile

SBE SEA-BIRD ELECTRONICS, INC.

13431 NE 20th St. Bellevue, Washington 98005 USA

Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Service Report

RMA Number 60943

Customer Information:

Company	Lockheed Martin	Date	9/21/2010
Contact	Domenic Jannarelli		
PO Number	8-290900		

Serial Number	43F0147
Model Number	SBE 43F

Services Requested:

1. Evaluate/Repair Instrumentation.
2. Perform Routine Calibration Service.

Problems Found:

Services Performed:

1. Performed initial diagnostic evaluation.
2. Performed "Post Cruise" calibration of the oxygen sensor.
3. Performed full diagnostic evaluation.

Special Notes:

SEA-BIRD ELECTRONICS, INC.

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0147
CALIBRATION DATE: 31-Aug-10p

SBE 43F OXYGEN CALIBRATION DATA

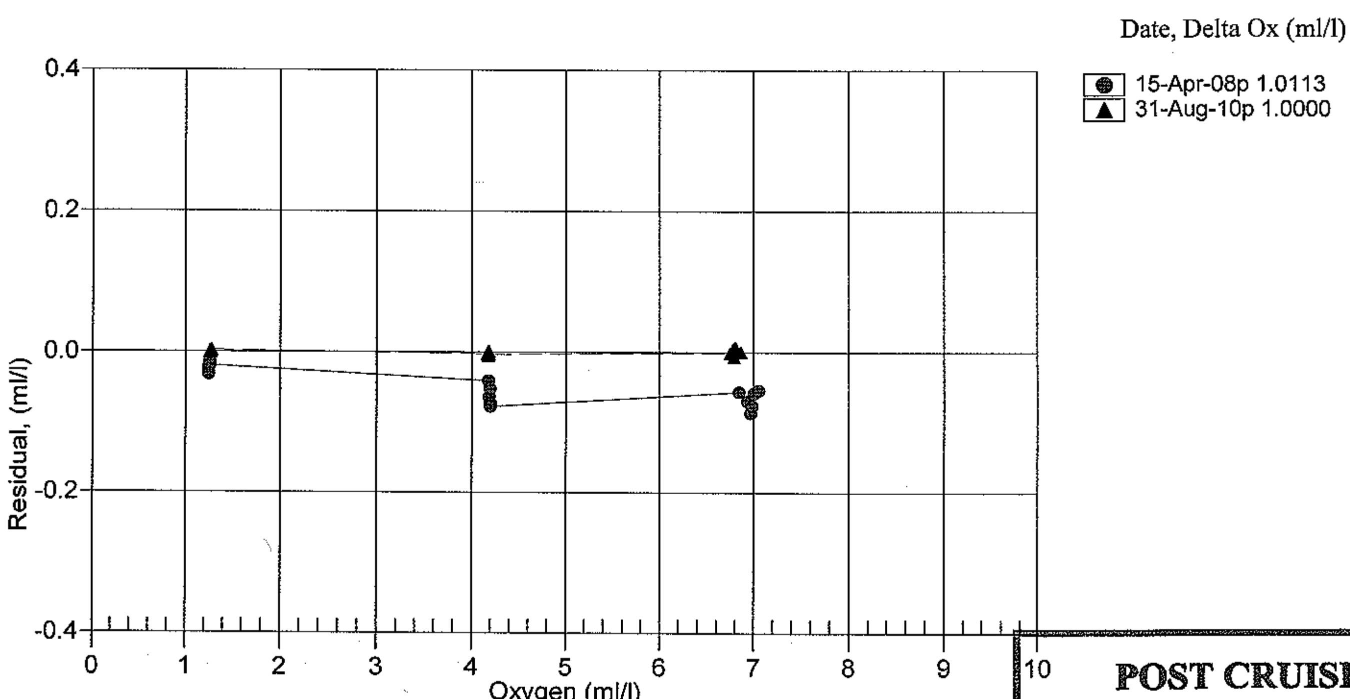
COEFFICIENTS
Soc = 2.2620e-004 (DI)
Foffset = -897.85
Tau20 = 1.08

A = -1.6423e-003
B = 1.7358e-004
C = -2.9544e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(Hz)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.26	6.00	0.01	1538.53	1.26	-0.00
1.26	12.00	0.02	1637.06	1.26	0.00
1.26	2.00	0.01	1477.16	1.26	0.00
1.27	20.00	0.02	1768.87	1.27	0.00
1.27	26.00	0.02	1869.87	1.28	0.00
1.28	30.00	0.02	1943.10	1.28	0.00
4.16	6.00	0.01	3018.66	4.16	-0.00
4.17	12.00	0.02	3337.97	4.16	-0.00
4.17	2.00	0.01	2807.97	4.17	-0.00
4.18	20.00	0.02	3763.80	4.18	0.00
4.18	26.00	0.02	4077.70	4.18	-0.00
4.18	30.00	0.02	4298.17	4.18	-0.00
6.74	30.00	0.02	6384.96	6.74	-0.00
6.78	12.00	0.02	4872.31	6.78	0.00
6.78	20.00	0.02	5546.35	6.78	-0.01
6.80	26.00	0.02	6078.73	6.80	0.01
6.80	6.00	0.01	4366.39	6.80	0.00
6.86	2.00	0.01	4041.59	6.86	0.00

Oxygen (ml/l) = Soc * (F + Foffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
F = frequency output from SBE43F, T = temperature [deg C], S = salinity [PSU] K = temperature [deg K]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]
Residual = instrument oxygen - bath oxygen



POST CRUISE CALIBRATION